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Final Report

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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;
- To create employment in new or existing industries;
- To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

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The Maidstone Conservahome

The Retrofit and Rehabilitation of a 1920s Rural House in the Prairies

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By

The Saskatchewan Research Council

And Supported By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leaders: Dave Eyre and Dave Jennings

Miscellaneous
Report FP-19

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This report gives details of the retrofit work conducted on a house in Maidstone in Saskatchewan, as part of the Conservahome Project. The Project involved the retrofit and rehabilitation of six houses of various ages and styles, and was funded by CREDA: the federal-provincial Conservation and Renewable Energy Demonstration Agreement. For further details of the project the reader is referred to the Overview Report which makes up part one of this series.

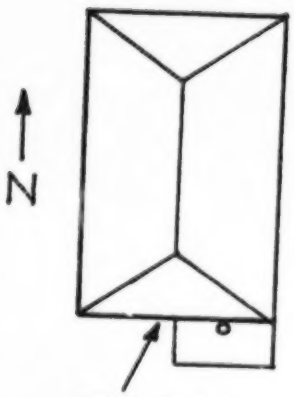
Maidstone is a small town located on the edge of the heavy crude oil deposits in north-western Saskatchewan. There were three main reasons for choosing this town as a site for one of the Conservahomes:

- It presented an opportunity to include an oil-heated house in the project - all other locations being predominantly gas-heated.
- It presented an opportunity to investigate the particular problems of retrofit in an essentially rural situation.
- The area around Maidstone was experiencing a development boom due to exploitation of local heavy crude deposits, and it was anticipated that this would ensure a good re-sale potential on the retrofitted house.

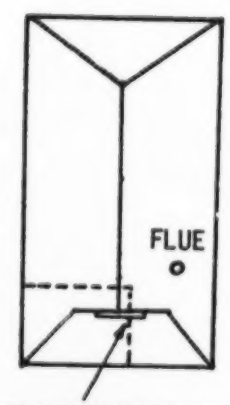
When it came to selecting an appropriate house in Maidstone, it was found that only two houses were up for sale at the time, and neither was particularly suited to the demonstrational aspects of the project. Nevertheless, it was necessary to choose one of them. Both were of 1920's vintage, with many features in common. The selected house was the more dilapidated of the two, but its basic structure was generally in better condition - which was the main reason for choosing it over the other.

The Maidstone Conservahome is the oldest of the six houses in the project. It was in bad condition for a house of its age. Under normal circumstances, the

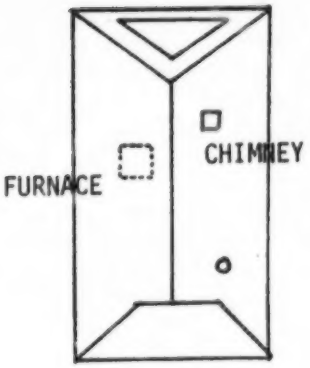
home owner might have some difficulty in deciding whether to upgrade it or tear it down and replace it. Therefore, viewed as an economic exercise, the work on this house would be hard to justify in a general way. However, because of the poor condition of the house, it contained virtually all of the heat-losing features that can be found in houses of that age and type. Accordingly, it was felt that the house would be valuable as a means of demonstrating a wide range of retrofit measures.



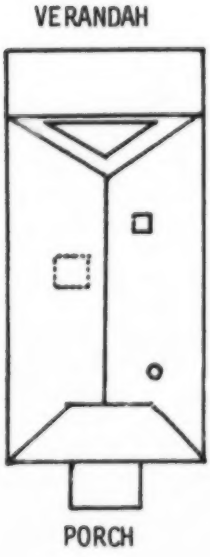
The house is located in the town of Maidstone at Lot 9, Block 13, Plan B3702. It was built in 1920 or 1921. Its history and its original shape can be deduced from some of the constructional features and from limited information supplied by the current realtor. The original shape was probably rectangular with a small extension on the south. The house had a short foundation wall, about 200 mm wide by 600 mm deep, surrounding a bare soil crawl space. Part of this crawl space was excavated to house a concrete-lined water cistern, a concrete-lined coal bunker and other miscellaneous storage space. Access to the basement was by a staircase that has since been removed. The house was totally uninsulated and had no vapour barrier. It was heated by a coal-fired stove located in the southern extension.



It has since been subjected to two major alterations and an assortment of remedial work of varied quality. It is believed that the first alterations were carried out before 1950, and it is deduced that these were as follows. The south extension was extended even further to give a rectangular floor plan. The roof line of the extension was blended into the existing line, with a dormer window on the south gable. The foundation was carried around the base of the extension, and the redundant section of the original foundation wall was removed, leaving two stub walls protruding into the crawl space. The dugout basement was extended to cover most of the available area under the house, and probably left the basement in the shape in which it can be seen today. The south end of the house was converted into a kitchen and bathroom. The staircase into the basement was relocated by the kitchen. Another staircase was installed above it, leading from the bathroom to the attic. Space limitations created some design problems, and the attic staircase is approached rather awkwardly from behind the bath-tub. After the basement staircase had been relocated, the original one was blocked in and an existing bedroom was extended into the space produced by this modification. The original bedroom door was blocked in and converted to a shallow shelf space. A new bedroom door was provided.



The attic was developed as a narrow room extending the full length of the house, with dormer windows at each end. The floor joists were covered with 25 mm shiplap over the entire attic area. The final step in this alteration was to dispose of the coal-fired stove in the kitchen and replace it with an oil-fired forced air furnace in the basement area. The existing stove flue was capped off in the kitchen, and replaced by a brick chimney at a new location. A hole was cut in the living room floor and the new furnace was dropped into position on a prepared concrete pad. The coal chute was capped and plugged with concrete. Air heating ducts and outlets were installed, and it is likely that most of the electrical wiring was either installed or upgraded at this time.



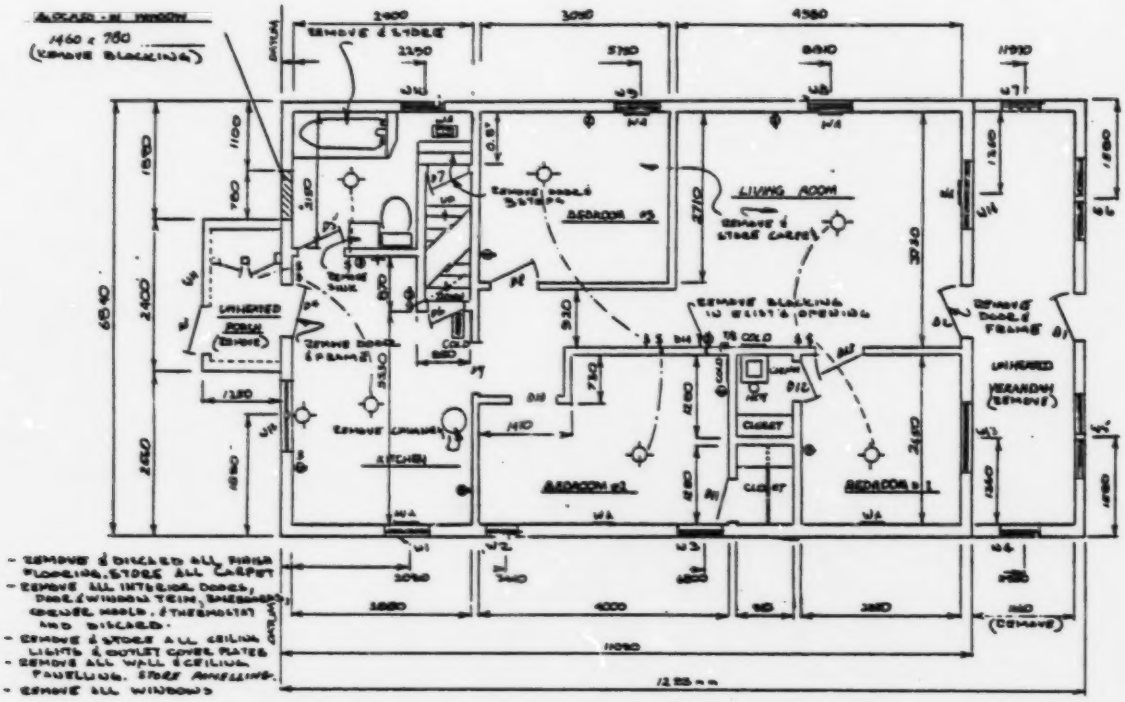
The second alteration project is believed to have taken place in the 1960's. The standard of workmanship was very poor, making it easy to distinguish this alteration from earlier ones. The dugout basement area was probably extended at this time, and the soil was removed through two openings in the foundation wall (which may have been put in at an earlier stage). Most of the exposed soil was parged and the concrete floor was extended. An unheated verandah with four large windows was installed on the north of the house, extending the full width. A small, unheated porch was built around the back door on the south. Concurrently with these alterations (according to the realtor) the exterior walls were partly insulated with zonolite and re-finished internally with a fibreboard material known locally as 'beaverboard' or 'tentest'. The whole exterior was finished with rough stucco, with pilastered corners and simulated blockwork along the foundation wall.

Since then there have been various minor attempts at making the house warmer. The bathroom window on the south wall was blocked in, a new oil furnace was installed in the early 1970's and the ductwork was improved at that time. There is evidence of various attempts to cover the windows with some kind of storm windows. Three of the windows are fitted with good quality aluminum storm units.

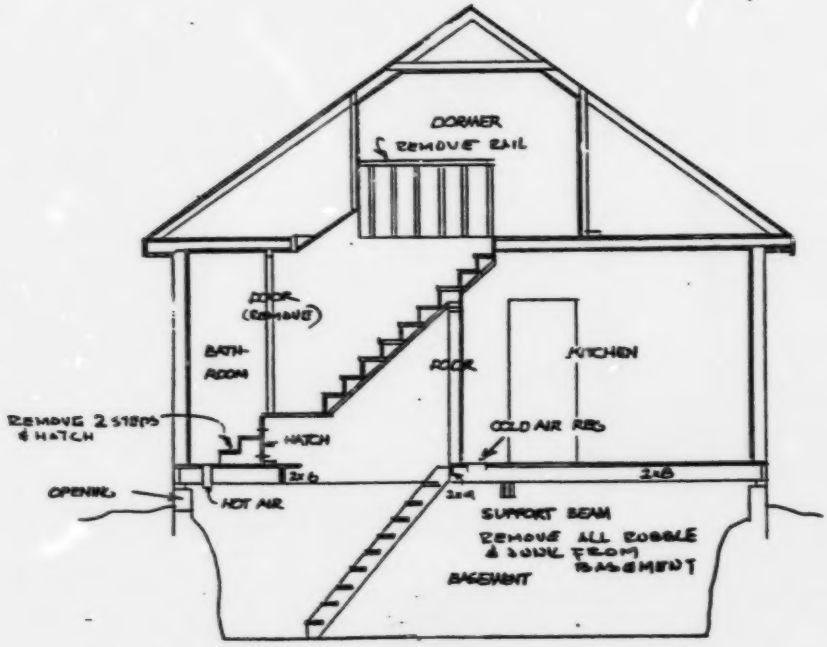
The house has been allowed to fall into disrepair over the last few years. It was condemned around 1978 and may have been standing unoccupied for some considerable time. It changed hands sometime between 1978 and 1980, and was given an interior facelift. This consisted of the application of ceiling tiles and panelling over the deteriorated ceiling and walls. The work was generally of a poor standard and appears to have been aimed at rehabilitating the house at minimum cost. Most of the deterioration had been caused by leaking shingles, which were estimated to have been installed around 1963. These shingles were not replaced during the rehabilitation, and the new ceiling tiles had become discoloured by further leakage through the roof.

Plans and elevations of the house, in the condition in which it was purchased for this project, are shown in figure 1.

Fig. 1. Plans and elevations of house


LIVING ROOM
BEDROOM #3
BEDROOM #2
BEDROOM #1
KITCHEN
UNHEATED PORCH (REMOVE)
UNHEATED VERANDAH (REMOVE)
CLOSET
CLOSET
REMOVE BLOCKING IN EXIST'G OPENING
REMOVE DOOR & FRAME
REMOVE & STORE CARPET
REMOVE DOOR & FRAME
REMOVE & STORE
REMOVE & DISCARD ALL FINISH FLOORING. STORE ALL CARPET
REMOVE ALL INTERIOR DOORS, DOOR & WINDOW TRIM, BASEBOARD MOULD. & THERMOSTAT AND DISCARD.
REMOVE & STORE ALL CEILING LIGHTS & OUTLET COVER PLATES
REMOVE ALL WALL & CEILING PANELLING. STORE ANNELLING.
REMOVE ALL WINDOWS

MAIN FLOOR PLAN



SECTIONAL VIEW LOOKING WEST

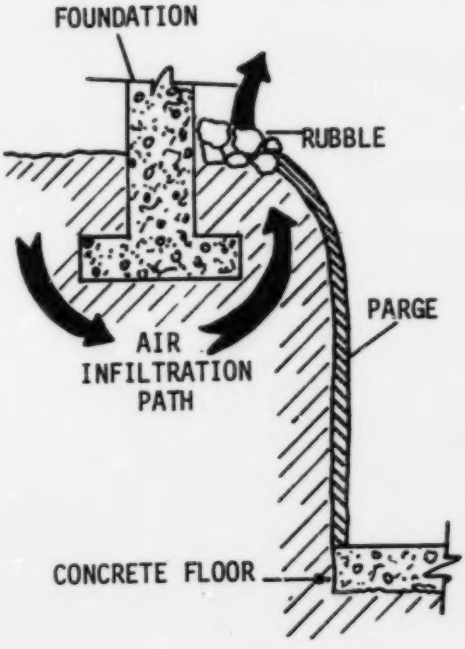
At the time of purchase and preliminary inspection of the house, it had been occupied intermittently for at least a year and was being rented by a family of three.

The oil consumption records had not been kept by the occupants. The oil supply company had some records, but these could not be found without difficulty, and the attempt was therefore abandoned. The oil consumption and heating degree days were monitored for a 26-day period in February 1979. The total consumption in this period was 154 imperial gallons, at a cost of $94. Pro-rating this to the annual heating degree-day figure (approx. 6,000 Celsius degree-days), it was estimated that the house would consume an equivalent of 300 million Btu's of oil per year. It was estimated that, by 1983, this would entail an annual space heating bill of about $2,000.

No attempt was made to estimate the space heating requirements of the house from the areas and R-values of the various components of the building envelope. The walls and ceiling had no insulation, and their construction was so leaky that R-values would be influenced appreciably by air movement through these features. Accordingly, it was felt that it would be impossible to estimate the actual R-values to an acceptable level of precision.

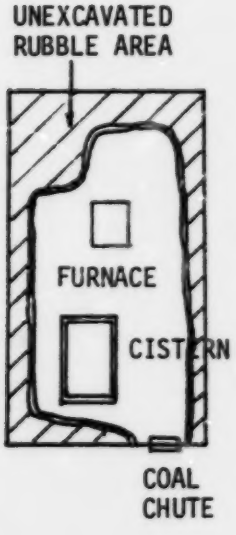
Airtightness tests were conducted on the house by a consultant. These showed an air change rate of 8 air changes per hour at a pressure differential of 50 Pascals. From this figure it is estimated that the house had a natural infiltration rate of .65 air changes per hour - confirming the leaky construction that was evident around the house.

The domestic hot water system was electrically heated. Because of the intermittent occupation it was virtually impossible to draw any conclusions about the annual power consumption of this facility.



4.1 Assessment

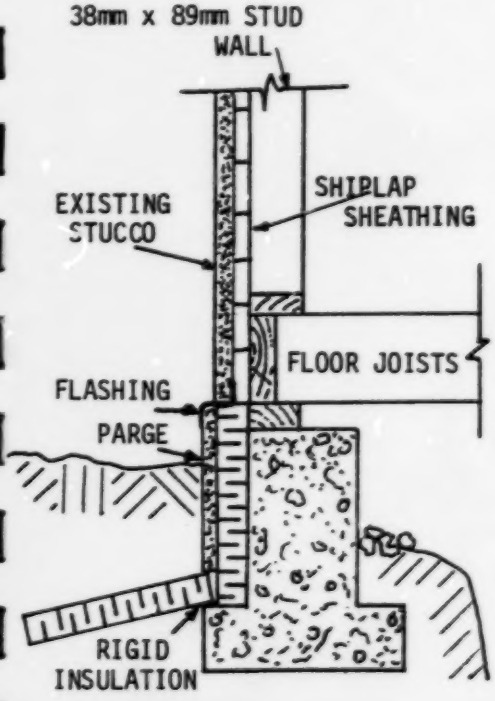
The basement is of the type known as a 'dugout'. It started off its life as a crawl space, and was then excavated to provide storage space and other facilities. About 70% of the available area had been excavated to give a headroom of about 2.2 m. The whole basement was surrounded by a concrete foundation wall, about 200 mm wide and 600 mm deep. The near-vertical sides of the dugout area had been parged, and in some places this parge had been carried along the top of the soil to the foundation wall. But in most places the soil surface had not been parged, and was left in the form of rubble. Of the excavated area, about half was taken up by the oil furnace and an unused water cistern. The concrete floor reflected the several stages of work that had been done on the house, and consisted of several sections, each at a different level. The whole basement area was too low and too broken up to serve as anything but a storage area.



The foundation wall contained several openings. These included a blocked coal chute, two openings for removing excavated soil, and several openings for pipes, oil lines and previous electrical service inlets. Only the coal chute had been blocked effectively; all other openings were blocked in a makeshift fashion and were contributing to the leakiness of the house envelope. The major source of air leakage in the basement was probably the unparged soil. Because of the shallowness of the foundation it was estimated that the soil would provide little resistance to air infiltration. This effect was further aggravated by rodent activity; the various mouseholes being a significant source of air infiltration.

4.2 Retrofit Alternatives

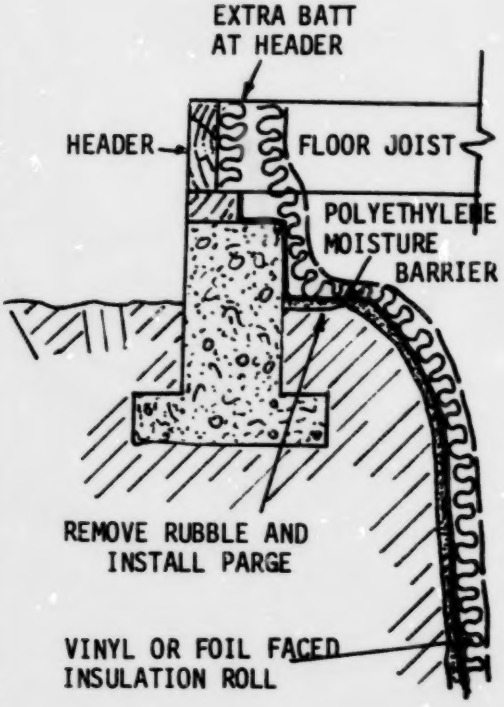
There were three main choices: either the basement could be insulated from the outside, or it could be insulated from the inside, or the main house floor could be thermally isolated from the basement, leaving it to operate as a cold basement or as a deep, unheated crawl space.



The outside approach involves the application of rigid insulation to the outside of the foundation wall, and a rigid insulation 'skirt' around the footings. This option has two advantages: it is relatively inexpensive, and it protects the foundation and footings from thermal cycling damage. The disadvantages are as follows:

- First, and most important, it would require a major soil disturbance around the foundation and footings. These had already been disturbed by excavations inside the basement, which had been carried too close to the footings in several places. The foundation appeared to be fairly sound, with no major cracks in evidence, but it was felt that any further soil disturbance might weaken them critically.
- This technique would create an unsightly jog on the exterior wall, and would require some major alterations to the stucco, which was considered to be in good enough condition to be retained.
- On its own, this option deals with only a small part of the basement envelope. Accordingly, the anticipated energy saving would be relatively small, and it would be necessary to conduct supplementary work inside the basement.

The second approach involves the sealing and insulation of the foundation wall, the parged area and the rubble area. This approach is necessary if the basement is to be retained as part of the heated section of the house. It will require some method



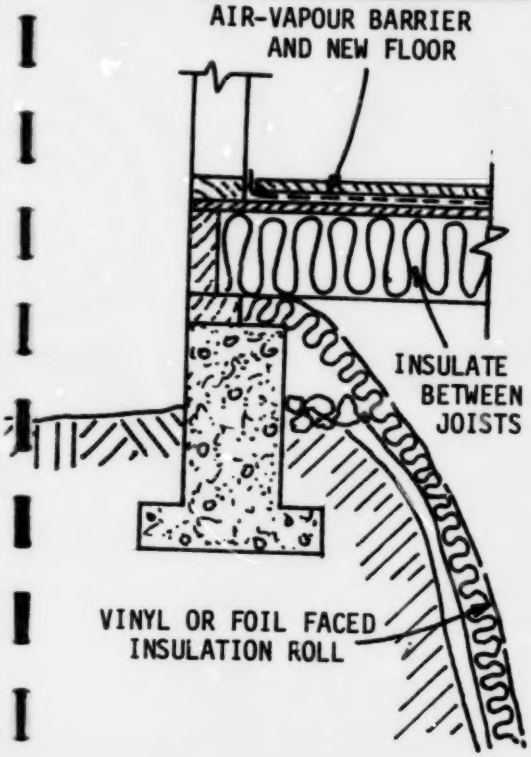
for sealing the unparged rubble areas, together with careful sealing work at all the other infiltration points around the basement. It requires different types of insulation, selected for the different problems presented by the various parts of the basement. The advantage of this option is that it achieves a substantial reduction in heat loss and retains the basement as a usable heated section of the house. The disadvantages are as follows:

- The retrofit work has several components, each being fairly labour-intensive. Therefore this is a relatively costly option.

- Even with careful retrofit work it is unlikely that a high thermal efficiency will be achieved in the basement, mainly because of the all the areas that are difficult to reach. If the basement is retained within the heated envelope of the house, it will probably make an appreciable contribution to the total air leakage of the house.

- By retaining the basement within the heated envelope of the house, it follows that the basement contributes to the heating load of the house. Where the basement is worth retaining in this way, the extra heat load can be justified, but where the basement serves no real function except as a storage area, it may consume energy unnecessarily.

The third option involves the operation of the basement as an unheated component of the house. To achieve this it is necessary to insulate and seal the floor above the basement. The advantage of this technique is that it makes the house more energy efficient by reducing the size of the heated area. Also, it is fairly easy to insulate and seal the main floor, provided there is good access above - which was so in this case. The disadvantages of this option are as follows:



- The basement needs to be maintained at a moderately warm temperature (above freezing) if it is to serve as a useful storage area. This means that the basement walls must be insulated, though not to the same level as in the previous option. Nevertheless, this adds to the cost of the retrofit.
- Exposed water pipes must be insulated, adding to the cost.
- The furnace ducting must be insulated, to reduce heat losses into the basement. This also adds to the cost.
- The furnace ducts need to be sealed, since they connect into the airtight house enclosure.
- This option probably results in a greater temperature cycling effect on the foundation wall, which may lead to structural damage.

4.3 Factors affecting the choice

The condition of the foundation wall was considered to be the most important factor, and none of the three retrofit alternatives were entirely satisfactory in this respect. The exterior approach would have disturbed the soil and weakened the foundation; the two interior approaches would require insulation on the interior face of the foundation, thereby insulating it from the warmth of the house and inducing greater temperature cycling effects. On balance, there was little to choose between the three alternatives in terms of their effect on the foundation wall. However, the interior insulation alternatives were potentially capable of producing higher levels of energy conservation. An interior approach was therefore selected.

The two interior retrofit alternatives differed essentially in the operation of the basement as a cold or warm part of the house. Under normal circumstances this would present the home owner with a difficult decision: the operation of the basement as a warm area would involve a relatively lower retrofit cost, but the annual fuel consumption would be higher. Conversely, if the basement were

to be retrofitted as a cold crawl space, the retrofit cost would be relatively high but the annual fuel consumption would be relatively low, since the heated volume of the house would be reduced. At the time when the retrofit decision was made, the information on costs and basement heat loss were not sufficiently accurate to permit a selection on the basis of cost-effectiveness.

The final decision was made as a result of two factors: the existing condition of the basement and the condition of the main house floor. The basement was clearly unsuitable for development as a heated living space. Also, the existing main floor was in poor condition, with an irregular surface and several weak spots resulting from the various openings that had been opened up and covered in during the lifetime of the house. It was felt advisable to install a new particle board floor on top of the existing one, and it was realized that this would present an opportunity to install a vapour barrier across the floor, thereby giving the right conditions for developing the basement as an unheated space. On further investigation it was realized that this would also be useful from a demonstrational point of view, since it would involve all the techniques that would normally be applied to an unheated crawl space. Therefore, since none of the six houses in the project had a crawl space, it was decided to retrofit the Maidstone basement as if it were an unheated crawl space.

4.4 Details of the upgrading work *

An old furnace unit and various bits of old furniture were broken down and removed from the basement.

The exposed rubble areas were cleaned up, and all the rubble was dropped inside the existing water cistern in the basement. This cistern was later capped-off, thereby removing a potential hazard for children.

* The detailed specifications for all upgrading work are given in Appendix I, which consists of specifications taken from the contract documents.

The cleared rubble areas were parged over with mortar to give a continuous seal across the floor and the raised areas in the basement.

Concrete pads were cast at various points on the floor, and a new system of support columns was installed to support the main house floor. These were adjusted to level off the main floor, as far as was possible. The existing array of support columns was removed.

Defective floor joists were identified. Some of these had suffered minor rot and rodent attack, others had been weakened by modifications and saw cuts. All weak sections were repaired and stiffened with plywood gussets nailed to each side of the joist section.

The two main wall openings were sealed with concrete blocks. An air vent was built into each opening to provide adequate combustion air supply to the furnace, and also to provide enough air movement through the basement to prevent odour build-up.

All unused openings, for old electrical service entries and old oil pipe lines, were filled and sealed with mortar.

At this stage the basement area was clean, well-sealed and ready for retrofit work. The floor above had been levelled and strengthened. A range of modification work was done on the electrical services, plumbing and furnace ducts at this time. This work is described in a later section.

The space between the joists of the main floor was insulated with glass fibre batt (RSI 4.9). This was then held in place and protected by panelling that had been stripped from the walls on the main floor.

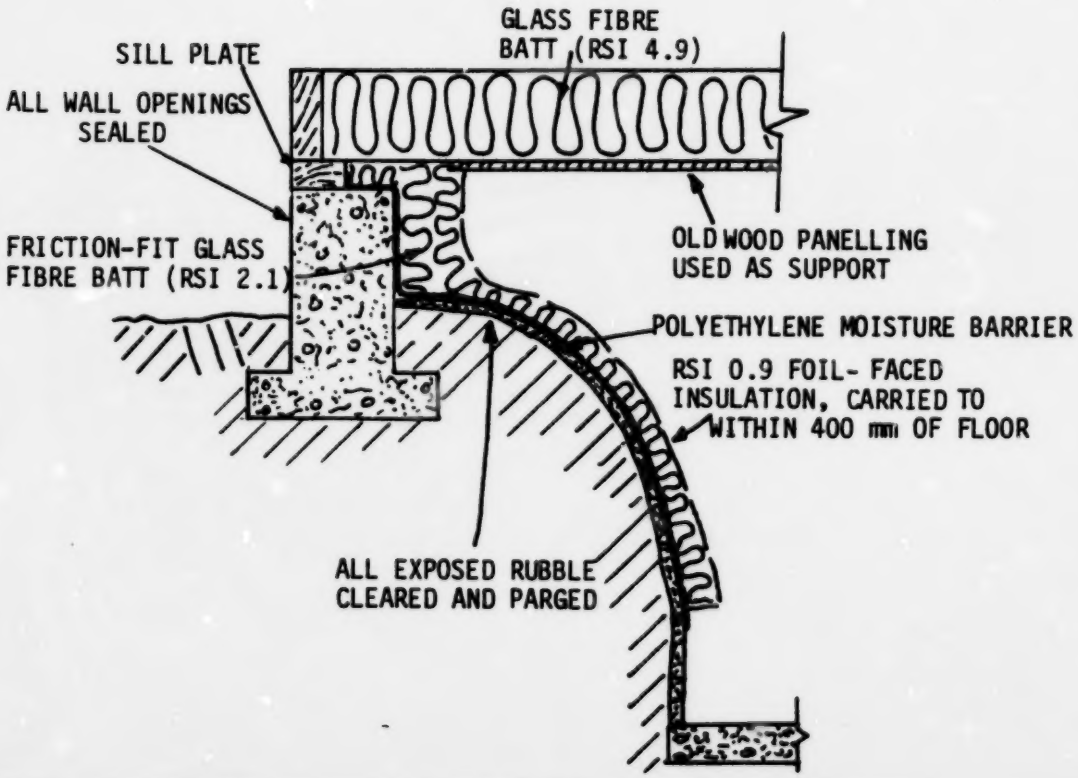
A 0.15 mm polyethylene sheet was attached to the foundation sill plate and draped over all parged surfaces. (Note this moisture barrier is necessary

to minimize moisture migration through the parging into the insulation to be applied over the parged areas).

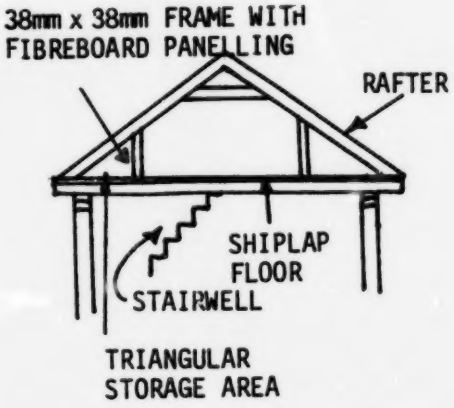
The exposed faces of the foundation wall (i.e. concrete grade beam) were then insulated with glass fibre batt material (R.S.I. 2.1), cut to fit between the bottom of the floor joists and the parged surfaces.

Foil-faced glass fibre blanket (R.S.I. 0.9) was attached to the underside of the floor joists against the foundation wall, and was then draped over the polyethylene moisture barrier. Where the parged areas were almost vertical, the blanket was carried to within 400 mm of the floor. (Note the uninsulated space at floor level allows some heat loss in order to maintain soil temperatures beneath the footings, close to the original conditions before retrofit). Where the parged areas were mainly horizontal, the blanket was carried across the parged surface for at least 2 metres. (Note that there are not many C.M.H.C.-approved materials for this type of residential application; the material used in this application was approved for commercial applications only.

The finished basement insulation work is shown in the following sketch:



5.1 Assessment

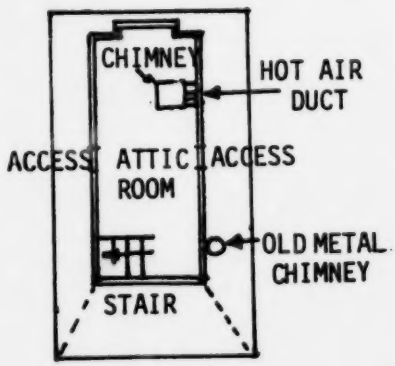


The roof construction was of rafter type, and the attic space had been developed as a living area that appeared to be little used.

The shingles were in an advanced state of disrepair. Considerable water leakage had occurred over a period of about two to three years (as deduced from available evidence). The roof was sheathed with 25 mm shiplap This showed extensive water staining, but there was no significant deterioration or rot.

The floor of the attic area consisted of 25 mm diagonally-laid shiplap on 38mm x 89 mm joists spaced 400 mm on centres. The space between the joists was uninsulated, except for a thin layer of sawdust in some places.

The attic room was constructed on top of this floor. It consisted of a light 38mm x 38 mm wood frame and ceiling section, covered with fibre board (Tentest) on the room side. The room ran for the full length of the attic, and was provided with a dormer window at each end. Both windows were in an advanced state of disrepair, with paint flaking, some rot, and some major infiltration openings. The ceiling headroom was about 1.80 metres. There was no insulation anywhere around the room or between the roof rafters.



A triangular storage space existed on each side of the room, and below the windows at each end. The space was accessed through two openings - one in the approximate centre of each long wall.

A brick chimney stack passed through the room near the north end, and the unused metal chimney from the kitchen passed through the roof in the triangular storage space section. The flashing around the brick chimney stack had deteriorated and was a source of water leakage. The flashing around the old metal chimney was in acceptably good condition. Both chimney's were poorly sealed where they passed through the ceiling of the main storey.

A hot air duct was routed into the room on the east side of the chimney stack. It was routed through one of the closets in the main storey. When the house was being inspected - in December - the climatic temperature was low, the duct was supplying warm air, but it was having very little effect in raising the temperature of the attic space.

The attic space was accessed through a stairwell connecting into the bathroom, and provided with a door. The bottom of the attic stair was located behind the bath-tub (see figure 1), and was awkward to negotiate.

In total, it was felt that the attic space was responsible for a major proportion of the heat loss from the house - both by virtue of the lack of insulation, and by the the considerable air leakage paths that were evident in all parts of the attic enclosure.

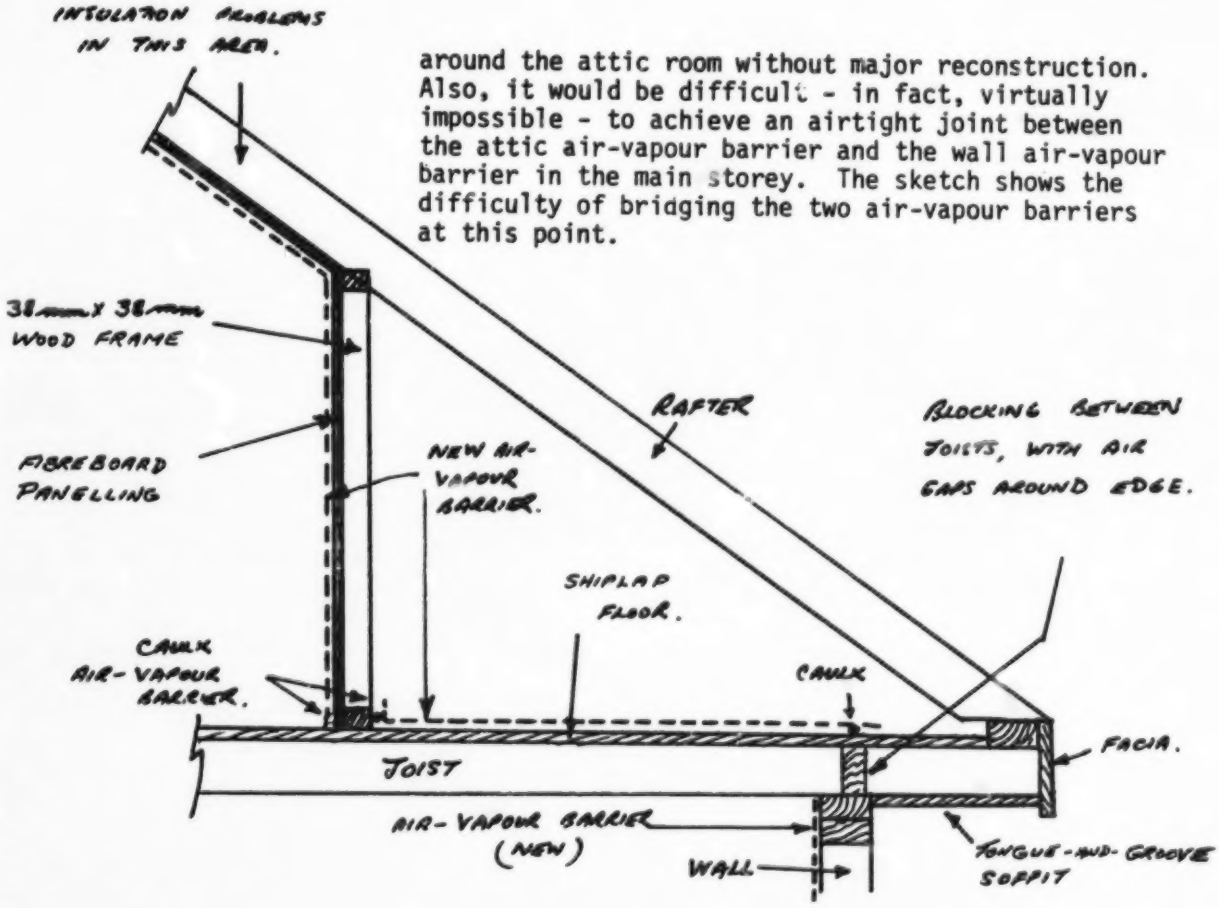
5.2 Retrofit Alternatives

There were two clear retrofit alternatives:

- To retain the attic room and retrofit around it.
- To eliminate the attic room and retrofit the attic as an undeveloped space.

The first alternative was considered the less desirable of the two. It would involve a larger heated volume, a larger heat-losing surface, and therefore larger fuel bills. The cost of retrofit would be higher in this case, since intricate work would be needed to insulate and apply an air-vapour barrier around the attic room. Also, some extra costs would be involved in replacing the windows with suitable energy efficient units.

One of the main problems with this approach would be to achieve an airtight vapour barrier construction. It would be difficult to route the air-vapour barrier



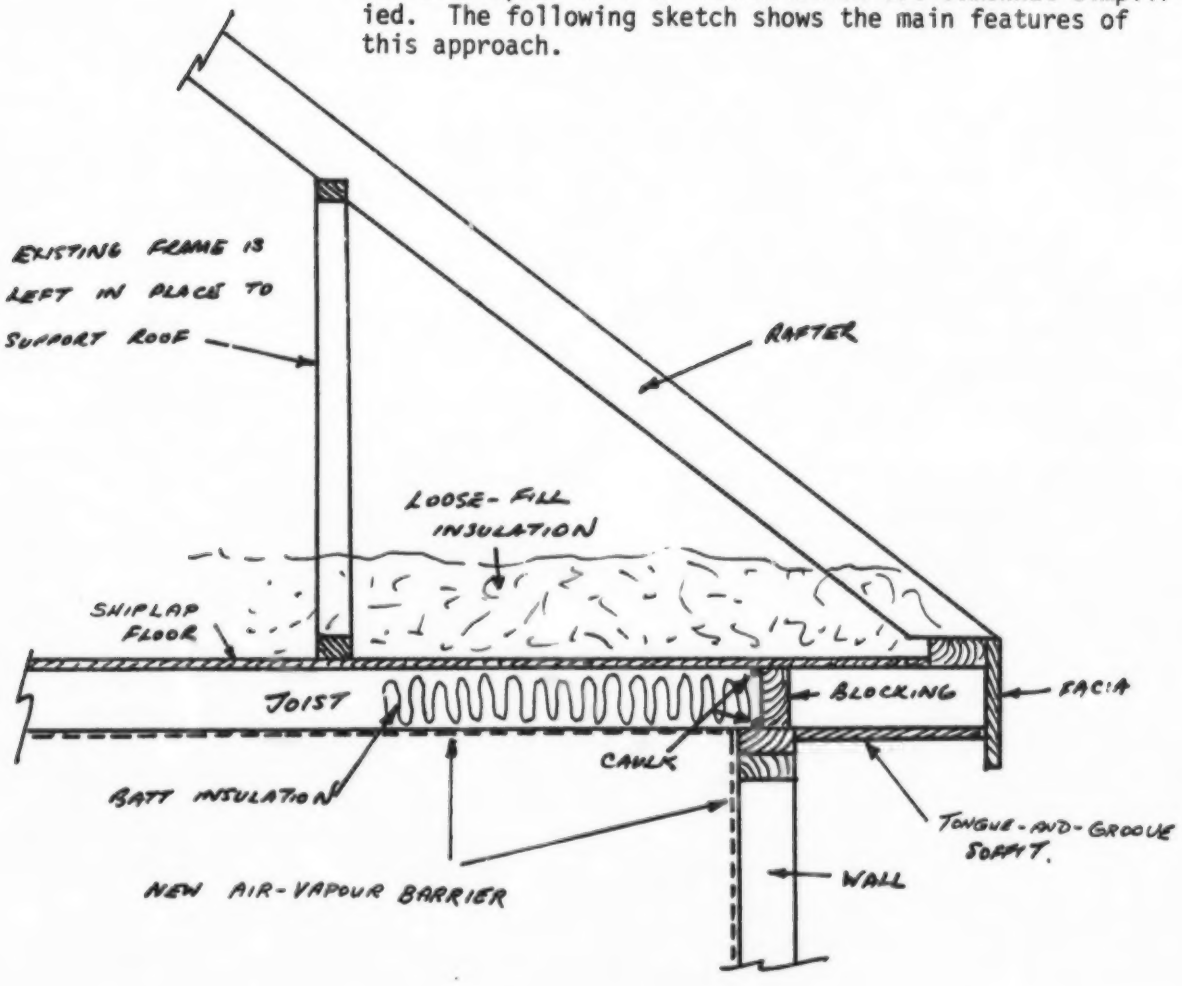
around the attic room without major reconstruction. Also, it would be difficult - in fact, virtually impossible - to achieve an airtight joint between the attic air-vapour barrier and the wall air-vapour barrier in the main storey. The sketch shows the difficulty of bridging the two air-vapour barriers at this point.

The construction at the outside edges of the attic floor is a major air infiltration point, and there is no easy way of sealing this, without major reconstruction work. Note also that there is a problem in achieving continuity of the air-vapour barrier at the foot of the 38 mm x 38 mm wall. Ideally, the air-vapour barrier should be run under the bottom plate of the dwarf wall and up the face of the fibreboard. But this would require removal of the dwarf wall first. The best course is to terminate the vapour barrier on each side of the bottom plate, using this plate to bridge the gap between the air-vapour barriers.

Insulation is a problem on the sloping sections of the attic room ceiling. The rafters are only 89 mm deep, which limits the amount of insulation that can

be inserted. Therefore, if possible, it would be advisable to use insulation with a high RSI per unit thickness at this point - such as rigid foam board. However, the shingle nails protrude into this gap, making it very difficult to inert anything except loose fill insulation. The typical insulation level that could be achieved in this area would therefore be around RSI 2.0.

With the second alternative - retrofitting the attic as an undeveloped space - the problems of insulation and air-vapour barrier installation are somewhat simplified. The following sketch shows the main features of this approach.



The fibreboard wall panelling is removed to give ease of access for installing the insulation. The dwarf walls are retained to provide roof support. A new air-vapour barrier is installed continuously across the ceiling and down the exterior walls. The main problem is then in dealing with the space between the joists. This is a major channel for air infiltration. Air can enter the space through the soffits, then flow across the ceiling between the joists, then exit through the opposite soffit. This can expose the ceiling to cold air, thereby short-circuiting the effect of the attic insulation. The solution, if possible, is to seal the joist cavity by caulking around the blocking at the top of the exterior walls. For this, it is necessary to remove the ceiling surface. This creates an opportunity to add insulation in the joist cavity. It is not strictly necessary to add insulation here, since the attic insulation will be adequate once the joist cavity is sealed. The insulation will have to be batt type, which, by differing from the loose fill in the attic, will add to the insulation costs. It is considered, by the authors, to be good practice to insulate this space. The insulation provides some slight resistance to air flow through the cavity, should the caulking fail at some later date.

Generally this second alternative will be simpler and cheaper than the first. Some additional costs will arise in closing off the stairwell, but these should not be as great as the several incidental costs involved in the first alternative.

5.3 Factors affecting the choice

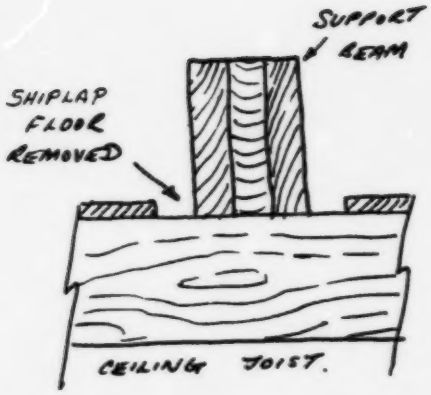
This was the first house to be chosen for this project. It was believed, at that time, that it might be difficult to secure another house with an attic room. Therefore, as bad as this example was, it was felt to present an opportunity to show how to rehabilitate and retrofit a poorly-built attic room. Subsequently, two other houses were secured with attic rooms of better quality. It was therefore decided that the Maidstone house could be used to demonstrate how to deal with an attic room by eliminating it.

This course of action was clearly the best option in this case. The room was not very useful, and had a low headroom. Also, its access, around the back of the bath-tub, was awkward, and would have eliminated some interesting options in developing the main floor area.

Accordingly, it was decided to eliminate the attic room and retrofit the attic as an undeveloped area. This decision was influenced mainly by practical and demonstrational considerations, but it could have been justified on the basis of cost effectiveness alone.

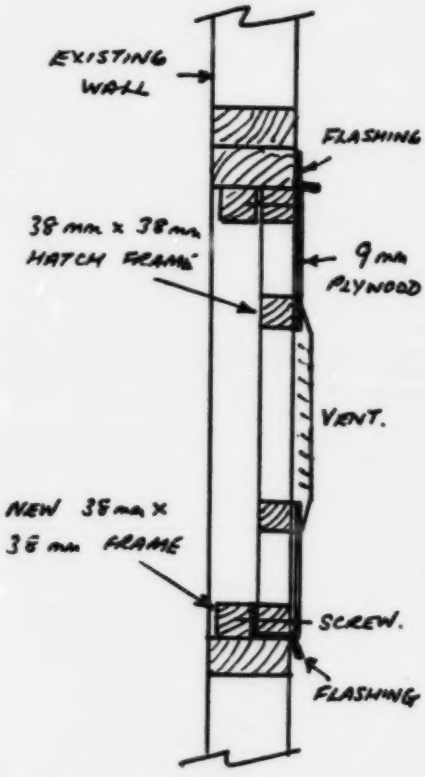
5.4 Details of the upgrading work

The first step was to replace the roof shingles, to prevent further water leakage into the house. At the same time, the old metal chimney was removed and the opening was patched at roof level. When the new shingles had been installed, the masonry chimney flashing was repaired.



During an early stage of the retrofit work it was discovered that the ceiling was sagging and was particularly weak over the main living room area. It was therefore decided to strengthen this section of the ceiling, and a supplement to the contract was drawn up for this work. A narrow section was removed from the attic floor (shiplap) across the living room ceiling. A three ply 38mm x 190 mm support beam was constructed and positioned in this section. The joists were bolted to this beam and pulled up into alignment. This remedial work emphasizes one of the pitfalls of retrofit work: inherent defects in the house may not become evident until the retrofit work is in process, and some supplementary work and cost may then become necessary.

It was originally proposed to remove the attic room completely, including the wood frame dwarf walls to give clear access for insulation work. But on reflection it was felt advisable to retain the framed walls as roof support. The fibreboard panelling was therefore removed, and this gave fairly good access to all parts of the attic.



The existing attic windows were removed and their cavities were re-framed. An attic vent was installed in the window cavity on the north, and a combined vent and attic hatch was installed in the cavity on the south. The finished attic was therefore provided with access and adequate ventilation. The vent sizes were approximately 203 mm x 305 mm, and the total vent area was therefore smaller than the 1 to 300 ratio required in the National Building Code 1980 - but this smaller area was justified by the higher levels of airtightness planned for the finished house.

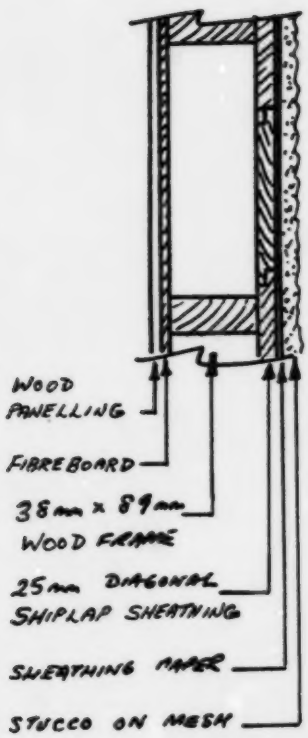
The existing staircase was removed, and the top of the stairwell, including the sloping ceiling section was framed in and covered with plywood in preparation for later attic insulation work.

The existing warm air duct to the attic was removed, and all electrical services in the attic were removed.

At this point some sealing and air-vapour barrier work was conducted at various points in the attic. These are described in the later section dealing with air-vapour barrier construction.

The entire attic floor was covered with 200 mm thickness of blown glass fibre, giving a thermal resistance of about RSI 5.0.

6.1 Assessment



The exterior walls were 38 mm x 89 mm wood frame on 600 mm centres, though with some considerable variations in spacing. The inside surface was covered with fibreboard over which wood panelling had been applied recently. The exterior of the framing was covered with diagonal shiplap sheathing (25 mm), sheathing paper and stucco on mesh. There was no vapour barrier, and no insulation except for a small section of the west wall in the living room area, where a small amount of vermiculite was discovered during subsequent retrofit work.

Until a few years previously, probably around 1978, all the wall surfaces and the ceiling were covered with fibreboard only. This had deteriorated on walls and ceiling, but particularly on the ceiling, which had sustained extensive discolouration due to water leakage through the defective shingles. An attempt had been made to rehabilitate the house by covering the walls with panelling (simulated wood grain finish) and by covering the ceiling with 305 mm square tiles. Subsequent water leakage through the roof had caused discolouration of the new ceiling tiles. The panelling had been attached poorly, and was visibly bowed at several points.

The room design showed obvious signs of re-modelling to accommodate the various changes in the house, as described in an earlier section. This had created some curious features, such as poor window location, poor door location, and the location of the attic stair access behind the bath-tub (see figure 1).

The floor showed a number of uneven and badly supported areas. Generally, it consisted of either a shiplap or tongue-and-groove sub-floor, with a linoleum tile finish.

The partition walls were mainly 38 mm x 89 mm wood frame construction, though some of the re-modelled sections consisted of 38 mm x 38 mm wood frames. Several of the wall sections showed signs of movement, and some door frames were visibly distorted out of square.

6.2 Retrofit alternatives

6.2.1 The exterior walls:

There were three obvious choices:

- Insulate the existing wall cavity by coring from the exterior and blowing loose fill or foam insulation into the cavity.
- The same, but by coring from the interior.
- Remove the interior wall finish, insulate with batt, install an air-vapour barrier and re-finish with gypsum board.

The rooms were too small to allow the addition of a new wood frame wall inside the existing one. Also, it was estimated to be less costly to utilize the existing wall cavity for insulation, rather than add new frames with insulation to either the exterior or interior.

6.2.2 The ceiling:

Here, there were two alternatives:

- Remove the existing tiles, install an air-vapour barrier on the exposed fibreboard, then cover this with new gypsum board.
- Remove both the ceiling tiles and fibreboard, insulate the space between the ceiling joists with batt insulation, install an air-vapour barrier and cover with gypsum board.

6.2.3 The floor:

Bearing in mind the decision to operate the basement as an unheated area, it was necessary to provide an air-vapour barrier across the floor. This would have to be protected by an underlay material such as particle board, which would alleviate some of the irregularities

in the existing floor. This was virtually the only option for treatment of the floor.

6.3 Factors affecting the choice

The stucco on the exterior walls was generally in good condition, apart from occasional cracks and some areas needing minor repair. The interior surface was in far worse condition, indicating that any work on the walls should be directed from the interior. The exterior walls had three basic problems: they had no insulation, no vapour barrier, and the interior surface required extensive rehabilitation. The complete removal of the existing interior surface would provide the opportunity to correct all three problems, and was therefore adopted as the retrofit strategy.

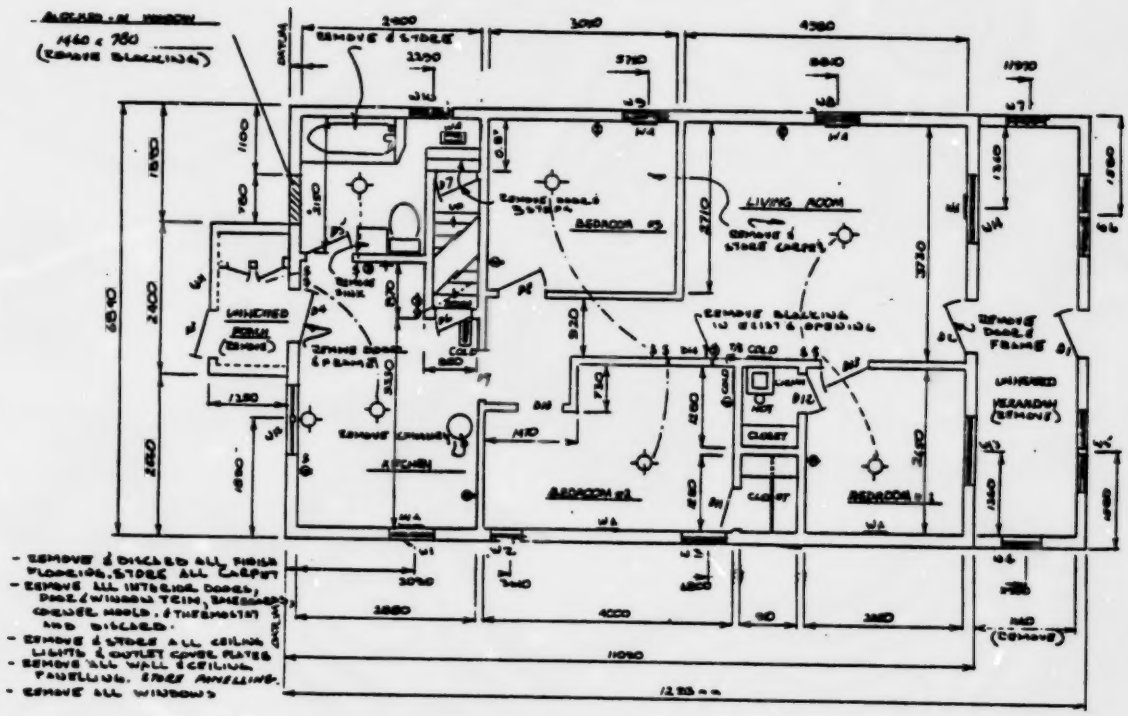
With the ceiling, the decision rested on whether to remove the existing surface completely, or cover it over with air-vapour barrier and new gypsum board. The first course would allow access to the top of the exterior walls, and would therefore make it possible to seal at the top of these walls and reduce the flow of cold air between the ceiling joists. This point has been discussed in section 5.2, where it was noted that this airflow could seriously limit the effectiveness of the attic insulation. It was therefore decided to strip the ceiling back to the joists, and seal and insulate this space before applying the air-vapour barrier and gypsum board.

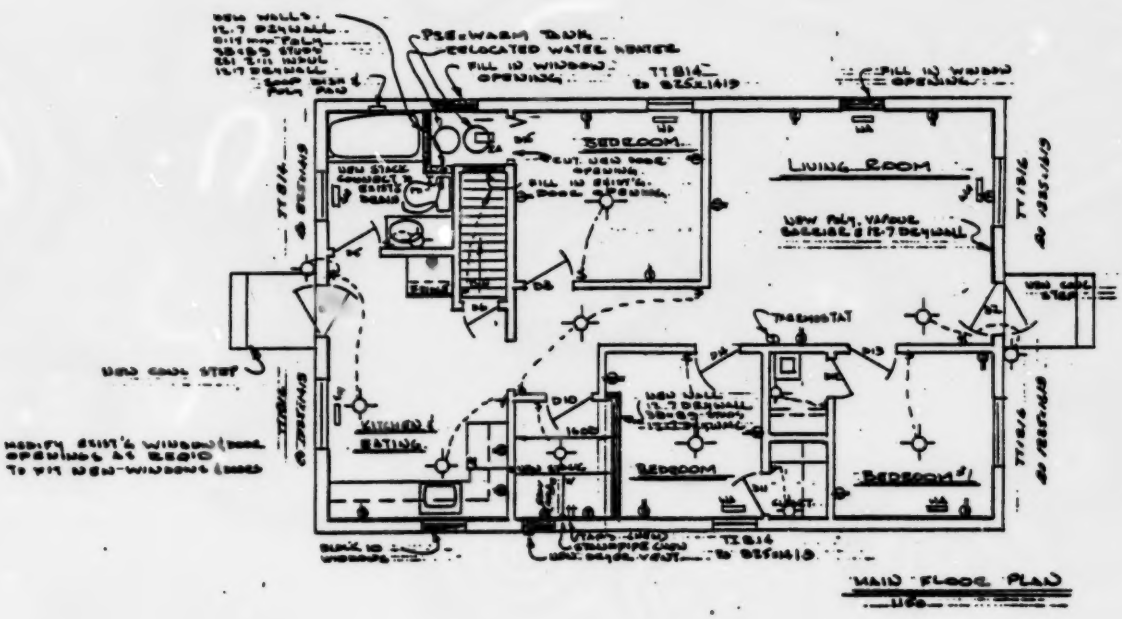
The decisions to eliminate the attic room and to operate the basement as an unheated area meant that the effective living area would be substantially reduced. The room layout and space allocation in the main storey were not suited to the new configuration of the house, and some re-modelling of the rooms was considered essential. The main storey plan, before and after retrofit, is shown in figure 2. The following changes will be noted:

- The elimination of the verandah and back porch, for reasons that will be given later.

- The re-modelling of the kitchen and bathroom to make better use of the available space.

Figure 2. Main storey floor plan before and after upgrading.


LIVING ROOM
BEDROOM #3
KITCHEN
BEDROOM #2
BEDROOM #1
CLOSET
UNHEATED PORCH (REMOVE)
UNHEATED VERANDAH (REMOVE)
- REMOVE & DISCARD ALL FINISH FLOORING, STRIP ALL CARPET
- REMOVE ALL INTERIOR DOORS, DOOR & WINDOW TRIM, BASEBOARD, CROWN MOULD, & THERMOSTAT AND DISCARD.
- REMOVE & STRIP ALL CEILING LIGHTS & OUTLET COVER PLATES
- REMOVE ALL WALL & CEILING PANELLING. STRIP ADHESIVE.
- REMOVE ALL WINDOWS
MAIN FLOOR PLAN



- The remodelling of bedroom #2 to give a smaller bedroom and a laundry room.

- Remodelling the area at the back of the bath-tub. This was originally the main access route to the attic stair, but after retrofit it became a small closet opening to bedroom #3 and housing the domestic hot water heating system. This design feature will be discussed later.

In total, these changes required some major reconstruction of partition walls. Therefore, in view of the decision to remove the surfaces of the exterior walls and ceiling, it was decided to extend this to the partition walls as well. Accordingly, as an overall strategy for the main storey, it was decided to strip all interior wall and ceiling finishes back to the wood frame. This strategy had several advantages:

- It simplified the re-modelling work.

- It simplified the extensive rehabilitation of the plumbing and electrical services (described later).

- It simplified the necessary repairs to some of the partition walls.

- It made it possible to attempt a high level of airtightness in the air-vapour barrier construction.

6.4 Details of the upgrading work

The electrical service was disconnected, and the water supply was shut off.

All wall and ceiling surfaces were removed back to the wood frame. The fibreboard and ceiling tiles were discarded, and the wood panelling was stored for use later as insulation support in the basement. During this work it was discovered that the south wall of the house had shiplap on the interior of the wood frame. This was probably an indication that the south wall had been installed as part of some earlier re-modelling work, thereby differing in construction from the rest

of the house. This leads to another point that must be considered when assessing a house for retrofit. Older houses often display evidence of re-modelling. In some cases this may be more extensive than appears from a simple examination. There may be hidden work that can create problems when the retrofit is conducted. In this particular case, there was some doubt as to the advisability of removing the interior shiplap, since it might be contributing to the structural stability of the wall. Eventually, it was decided to take the risk and remove the shiplap. There were no unfortunate consequences.

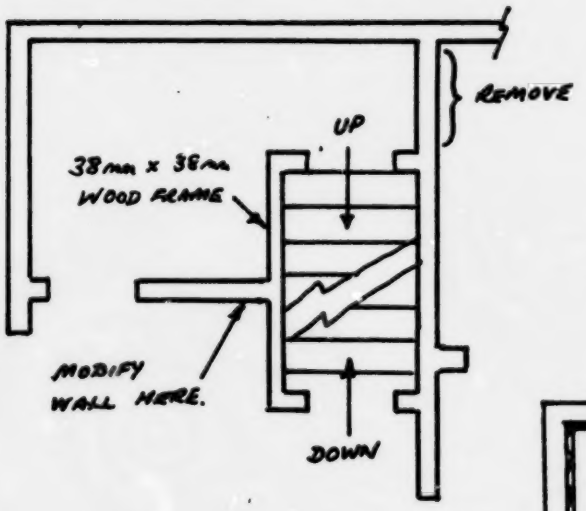
At the same time as the above work, the bathroom and kitchen fixtures were removed. The lavatory, the washbasin and the kitchen sink unit were in a dilapidated condition, and it was decided to replace them. Under normal circumstances this replacement might not have been necessary, but in this case the demonstrational aspect of the house was taken into consideration.

At this point all the existing plumbing, electrical and heating duct systems were removed or relocated. Details are given later.

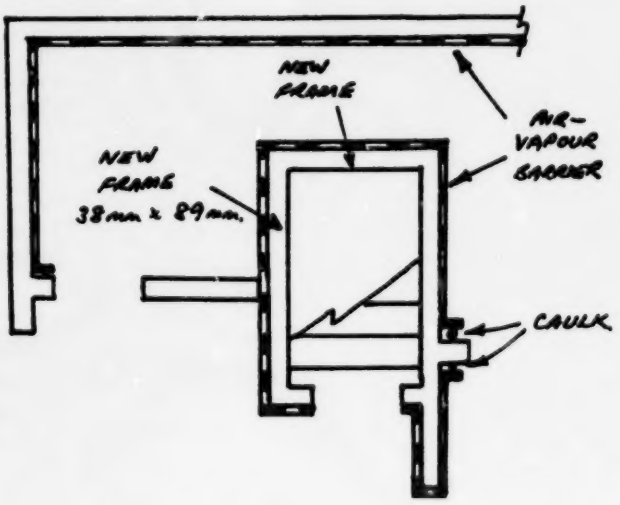
The existing partition walls were repaired and straightened where necessary. Non-standard walls (38 mm x 38 mm) were replaced with 38 mm x 89 mm wood framing.

As part of the re-modelling requirements, some sections of partition wall were removed and new sections were put in, as shown in figure 2. The work around the stairwell is of particular interest. The existing attic stair and doorway were removed. The south wall of the stairwell had a 38 mm x 38 mm wood frame, and was replaced by a 38 mm x 89 mm wood frame. This created some problems around the junction with the west wall of the kitchen, and some reconstruction was needed here also. It is important to note that the basement area was planned as an unheated area, therefore the stairwell wall has to be treated in the same way as an exterior wall. This means that it has to be insulated and provided with an air-vapour barrier. Since the stairwell

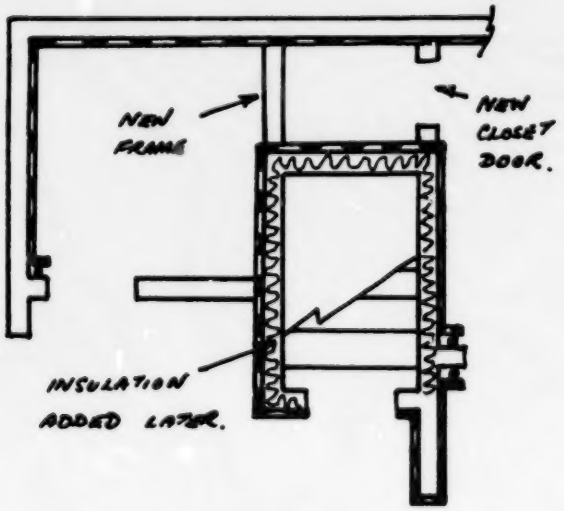
wall is joined to several partition walls, it is difficult to achieve continuity of the air-vapour barrier around the stairwell, unless this is carefully planned in the scheduling of the re-modelling work. The following sequence of sketches shows how air-vapour barrier continuity was achieved.



1. ORIGINAL SITUATION



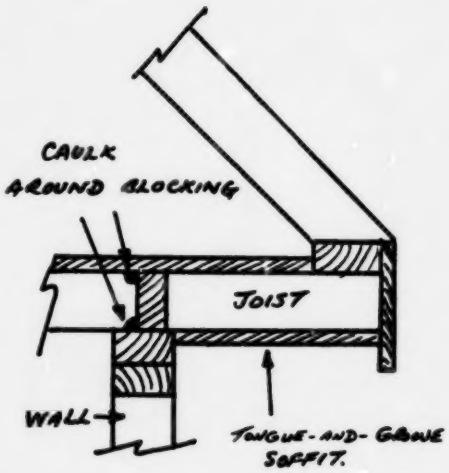
2. FIRST STAGE OF RE-MODELLING



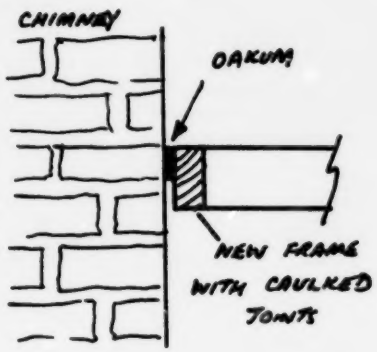
3. FINAL STAGE OF FRAMING

New electrical and plumbing systems were installed at this point, and the heating duct outlets - which had previously been mounted in the walls - were relocated in the floor at appropriate points around the house.

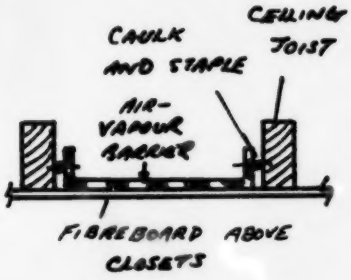
New doors and windows were installed. Details are given later.



Sealing work was conducted on the blocking above exterior walls, to reduce air infiltration through the soffits into the cavity between the ceiling joists. In most cases the blocking was a fairly good fit between the joists, and could be sealed by the application of caulk around the joints, but in some cases the fit was very poor and the gap was too wide to be sealed by caulking. In these cases the gap was sealed by the application of a urethane foam that can be purchased from some building suppliers in an aerosol form.



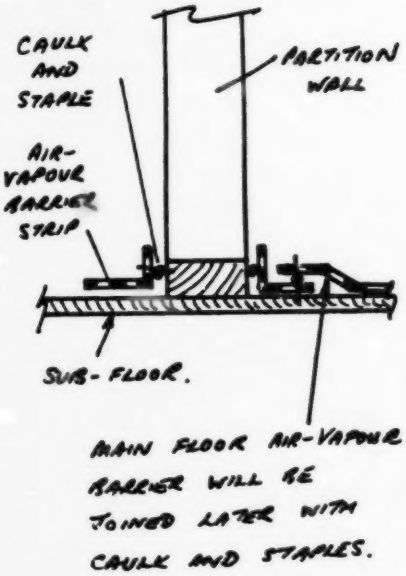
Because of the difficulties of operating inside the small closets, the contractor was not required to remove the fibreboard from the ceilings in the closets. This meant that the air-vapour barrier had to be installed from the attic in this part of the ceiling. With reference to figure 2 on page 25, it will be noted that this part of the ceiling is relatively complicated. It has the chimney stack passing through it, and a hole left by removal of the attic heating duct. The sealing and air-vapour barrier work were conducted in three stages. First, the existing shiplap floor in the attic was removed to give clear access around the chimney and above the closets. This was done at the same time as other preparatory work in the attic. The framing and blocking around the chimney was modified where necessary, to give a box frame around the chimney with a clearance of about 12 mm from the bricks. The joints in the box frame were sealed with caulk. The gap between the frame and the bricks was sealed by compressing strips of oakum into the gap. Next, sections of air-vapour barrier were installed between the joists above the closets. These were caulked and stapled to the joists. The edges were carried beyond the fibreboard above the closets, to be joined later to the ceiling air-vapour barrier applied from below. Any possible points of air leakage in this work were identified and caulked, as far as possible.



The same sealing procedure was applied around the chimney where it passed through the floor of the main storey.

Preparatory air-vapour barrier work was conducted at various points, as follows:

- pre-molded polyethylene enclosures were installed around electrical outlets in exterior walls and ceiling, and also around the soap holder in the exterior wall by the bath-tub.


CAULK AND STAPLE
PARTITION WALL
AIR-VAPOUR BARRIER STRIP
SUB-FLOOR.
MAIN FLOOR AIR-VAPOUR BARRIER WILL BE JOINED LATER WITH CAULK AND STAPLES.

- Cable openings were caulked at the outside studs of partition walls, where the air-vapour barrier could not be installed with convenience.

- Openings were caulked around heating duct openings, plumbing and electrical cables, where these passed through the floor of the main storey.

- Strips of air-vapour barrier were caulked and stapled around the bottom plates of partition walls to be joined to the floor air-vapour barrier at a later stage.

Details of this type of work are discussed in the EMR publication: "Air Vapour Barriers"*.

Once all the preparatory air-vapour barrier work was complete, the ceiling and walls were insulated with RSI 2.1 glass fibre batt. With the existing loose fill insulation in the attic, this brought the total thermal resistance of the ceiling insulation to RSI 7.1.

A six mil polyethylene air-vapour barrier was installed across the ceiling and down the exterior walls. The various sections of the air-vapour barrier were caulked and joined to make an airtight seal, as described in the publication referred to above. Also, the air-vapour barrier was caulked and sealed to the preparatory work around doors, windows, cables, outlets, etc.

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* Eyre, D. and D. Jennings, Air-Vapour Barriers. Ottawa: Energy, Mines and Resources. Fourth Edition, January 1983.

At the tops of partition walls the ceiling air-vapour barrier was folded down over the top plate, and was caulked and stapled to it. The same was done with the wall air-vapour barrier, where it terminated at a partition wall stud.

On completion of this air-vapour barrier work, a strip of air-vapour barrier was left protruding from the base of all walls - exterior and partition - to be joined later to the main floor air-vapour barrier.

The ceiling and walls were drywalled at this stage.

The main floor was cleaned, and any damage to the exposed air-vapour barrier strips were repaired. The floor air-vapour barrier was then installed, and was caulked and stapled to the exposed strips at the base of the walls. Some special attention and patching was needed around the bottom of door frames. Also, special attention was given to the caulking and sealing of the air-vapour barrier around plumbing and ducts, where they passed through the floor.

As soon as the floor air-vapour barrier was in place, it was covered and protected by the installation of an underlay material, consisting of 16 mm particle board.

7.1 Assessment

The location of doors and windows can be seen in figure 2 on page 25. The windows, before and after retrofit, are numbered for reference.

The kitchen window (#12) was a small fixed-casement unit; all others were double-hung wood frame units. Three of these had been fitted with aluminum-framed storm units within the previous two to three years.

All windows were in extremely bad condition: some of the glass was cracked, the putty had dropped out, many of the sashes and sills displayed extensive rot - to the point where holes were starting to appear in the sash. On one window (#9) the meeting rail on the upper section had rotted and fallen away from the glass, leaving a large gap. In another window (#8) a television cable had been brought into the house through the bottom sash. Extensive rot had opened the cable hole to a diameter of 12 mm or more. Extensive but ineffective work had been carried out with masking tape on most of the windows.

In figure 2 it will be noted that some of the windows were poorly positioned, probably as a result of re-modelling work. In some cases the re-modelling had made the window superfluous, as with window # 2, and possibly window #8.

At some earlier stage, the house had been fitted with a large window on the south wall of the bathroom. This had been blocked in, and the bathroom was served by window #10 on the west wall.

The kitchen window (#12) on the south wall was a very small unit, and was the only south-facing window. The passive solar utilization of the house was therefore minimal.

Both exterior doors were in poor condition, with poor seals around the edges. The front door was a unit designed for interior use. The back door was an exterior unit, with inset thin wood panels. The designs of

the two doors were not inappropriate, since one was protected by the verandah construction and the other was protected by the cold porch. However, neither the verandah nor the porch were in good condition, and it is unlikely that either offered any significant resistance to air infiltration.

7.2 Retrofit alternatives

With windows generally there are three retrofit options:

- Replace the unit.
- Upgrade the unit.
- Remove the unit and block in the opening.

Where the window is in moderately good condition, it may often be simplest and cheapest to upgrade it. Typical upgrading measures include repair of defective wood or cracked glass, installation of good weatherstripping materials, sanding and repainting all wood, re-puttying, and installation of storm units where these have been lacking. When the window unit is obviously beyond repair, it should be either replaced or blocked in. This last course is a justifiable retrofit option in some cases, particularly where the window has been placed in a poor location - either in the original design or as a result of re-modelling.

With exterior doors there are two options:

- Upgrade the unit.
- Replace the unit.

If the door is in fairly good condition (ie. with no rot and no extensive warping) , and if it is properly designed as an exterior door unit, it can be upgraded at relatively low cost. Options include repainting, installation of good weatherstripping, and in some cases the installation of a storm door unit. Where the door is in bad condition, or is not really suitable as an exterior unit, the proper course is to replace it.

7.3 Factors affecting the choice

The windows were in an advanced state of deterioration, and were obviously beyond repair. This left the options of replacement or blocking in.

The passive solar usage of the house was poor, and there was an opportunity to remedy this by increasing the window size on the south wall. The blocked-in window, existing on the south wall of the bathroom, offered an easy way of doing this. Another way was by increasing the size of the kitchen window on the south wall. Since this window was to be replaced anyway, the size increase would involve a small amount of extra work in modifying the exterior wall to give a larger opening.

Accordingly, the following retrofit strategy was adopted for the windows:

- Windows numbered 1, 2, 8 and 10 would be blocked in, since they would no longer be necessary for adequate lighting levels or through-flow ventilation in summer.
- The existing blocked-in window on the south wall of the bathroom would be opened up and provided with a new window.
- The south-facing kitchen window (#12) would be replaced with another unit of greater area.
- Windows numbered 3, 9, 13 and 14 would be replaced by new units with good thermal performance, with about the same size as the originals.

For reasons that will be discussed later, it was decided to eliminate the cold porch and the verandah. This meant that the house frontage would be modified, and windows #13 and #14 would face directly onto the street. Some consideration was therefore given to the sizing of these two windows. The elimination of window #8 meant that the living room would be totally dependent on window #14 for lighting. It was therefore

decided to retain the existing window area. The other window on the north wall of the house - window #13 - served only a small bedroom, and therefore did not need to be large. However, it was decided to retain the large existing area, since this would give two identically-sized windows at the front of the house. The two front windows had rough openings of 1225 mm x 1619 mm, and the replacement window units were selected to fit these openings as closely as possible. In retrospect, it is felt that it might have been better to reduce the window sizes slightly, since both windows were north-facing and were responsible for a significant proportion of the total heat loss of the house. A reduction of about 25% in window area would have reduced the heat loss, and would probably have had no serious effect on light levels in the living room. It is felt that not enough expertise on window and lighting design was brought to bear on the retrofit design. This is something that might be considered in future projects.

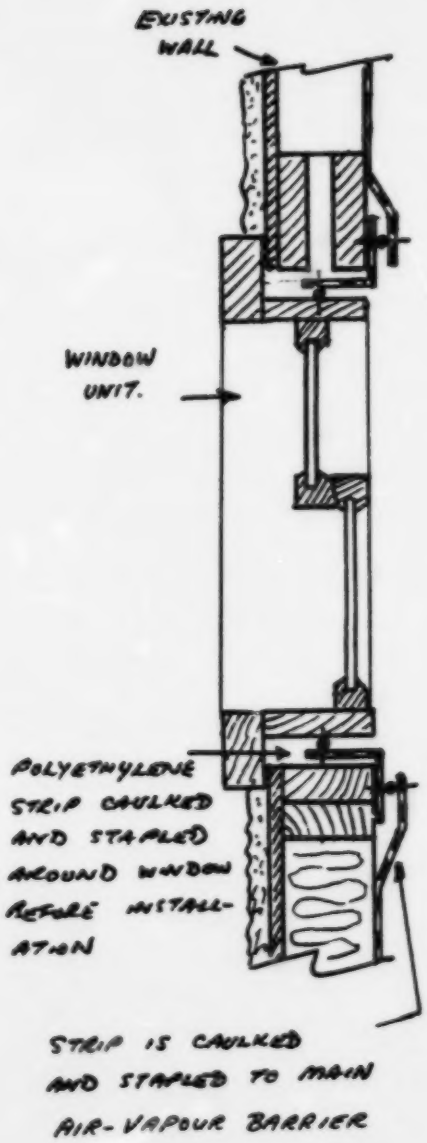
With the removal of the verandah and cold porch, greater demands were placed on the thermal efficiency of the two exterior doors. The existing units were totally inadequate, because of their poor condition and their poor thermal resistance. Accordingly, it was decided to replace the units with good thermal designs. Some emphasis was given to passive solar design by using doors with glass inserts on the south of the house.

7.4 Details of the upgrading work

Windows #1, 2, 8 and 10 were blocked in, covered with 25 mm sheathing and sheathing paper, and then were eventually stuccoed to match the existing exterior.

The blocked-in window on the south wall of the bathroom was opened up and prepared for window insertion.

The existing kitchen window (#12) was removed, and the rough opening increased to 1025 mm x 1419 mm to accept a larger window unit.


EXISTING WALL
WINDOW UNIT.
POLYETHYLENE STRIP CAULKED AND STAPLED AROUND WINDOW BEFORE INSTALLATION
STRIP IS CAULKED AND STAPLED TO MAIN AIR-VAPOUR BARRIER

Windows #3, 9, 13 and 14 were removed and discarded. The rough openings were modified slightly to accept new window units of approximately the same size as the original ones.

The existing exterior doors were removed and discarded.

All new window units were high quality single-hung type, with wood frames and 12 mm air-gap double-glazing. The units were selected on the basis of the good quality of the seals and the wood frame design. The windows were inspected before installation. Some were found to have defective seals. These units were returned to the supplier and were replaced with acceptable ones.

Combination units, consisting of a main door and a storm door, were installed at front and rear. Both units were of thermal door design, consisting of metal-clad urethane foam units for both the main door and the storm door. The south door unit was required to have at least 0.37 square metres of glass insert in both the main and the storm door. The weatherstripping materials and installation of the materials were of high quality.

All doors and windows were provided with a strip of polyethylene, wrapped and sealed around the outside of the frame, before installation. This preparatory strip of air-vapour barrier was later joined to the main air-vapour barrier on the walls.

The weatherstripping on the doors was checked and adjusted to give a good airtight seal, after installation.

The door at the head of the basement stair was essentially an exterior door. A solid core wood unit was installed, and weatherstripping materials of good quality were applied and adjusted.

8.1 Assessment

The verandah extended across the front of the house, and was provided with one window on each side and two windows at the front. The whole structure was in an advanced state of deterioration. The roof had not been properly joined to the main house structure. There was no flashing at the joint, and as a result there was considerable damage to the roof of the verandah, due to water leakage. The door and windows were in poor condition, with flaking paint, extensive rot and broken glass. The verandah foundation had shifted and the floor was tilted and uneven.

The porch was in fairly good condition, though it was of very poor construction. There were some signs of foundation settling, and the outer door had a broken section of glass, but there was no significant rot in the structure.

8.2 Retrofit alternatives

Generally speaking, verandahs and porches tend to improve the thermal efficiency of the house - particularly when located on the south of the building, where they can enhance the passive solar utilization of the house. Therefore, where possible or practicable, an attempt should be made to retain such features in the house.

In this case, the two structures were in too bad a condition to be retained. They would have had to be completely rebuilt in order to serve a useful function and present an acceptable appearance. Accordingly, it was decided to remove these units.

8.3 Details of the upgrading work

The electrical service mast and meter was removed from the side of the porch.

The porch and verandah were dismantled and discarded.

The exposed unstuccoed sections of wall were stuccoed to match the existing exterior finish.

New steps were installed at the front and back door, and a new concrete path was poured from the front door to the sidewalk.

New soil was added to the low area left by the removal of the foundation.

9.1 Assessment

The house was heated by an oil furnace unit, that was judged to be less than ten years old. On the basis of a simple inspection it appeared to be in good condition.

The heating ducts appeared to be fairly new and in good condition. The cold air and warm air registers were poorly sited for good heat distribution, and the warm air registers were mounted in the exterior walls.

9.2 Retrofit alternatives

There are generally two alternatives for dealing with an existing furnace:

- If it is an old unit, or is in poor condition, it should be replaced.
- If it is fairly new, or in good condition, an attempt should be made to maximize its efficiency by tuning it.

In older houses, some improvement in heating efficiency may sometimes be gained by relocating the duct runs and registers. This may often give only a marginal energy saving, and may therefore be non-cost-effective.

9.3 Factors affecting the choice

The furnace was considered to be in good enough condition to be retained. It was therefore decided to try to improve its efficiency significantly by a major re-tuning job. In retrofit, one of the problems with furnaces concerns the oversize factor: the unit may be appropriately sized for the house in its original state, but after the house has been made more energy-efficient, the furnace may be considerably oversized for its task. This oversize factor tends to

reduce the seasonal efficiency of the furnace. The capacity of the furnace can sometimes be adjusted to compensate, by reducing the nozzle size.

The major re-modelling of the main storey, together with the fact that the warm air outlets were located in the exterior wall, made it advisable to relocate the outlets and the duct runs.

Since the basement was to be developed as an unheated area, outside the heated envelope of the house, some major sealing and insulating of the ducts was necessary. When the furnace is mounted outside the air-vapour barrier of the house, all the heating and cold air return ducts break through this air-vapour barrier ducts, and part of the furnace unit, can therefore be regarded as an extension of the envelope of the house. If the ducts are subject to air leakage, then this leakage contributes to the general leakage performance of the house envelope. It is therefore necessary to seal all duct joints. Also, the air ducts, in passing through the unheated basement, will lose a considerable amount of heat to the basement. As a result, the furnace will deliver less heat to the house, and its effective efficiency will be reduced considerably. It is therefore necessary to insulate the ducts.

In considering the insulation of the heating ducts, some allowance must be made for deliberate heat loss into the basement. Ideally, the heating system should be allowed to spill enough heat into the basement area to retain its temperature slightly above the freezing point. This prevents plumbing problems, moderates the thermal cycling effects on the foundation, and provides a useful environment for cold storage.

Some consideration should also be given to providing a combustion air supply to the furnace. After parging, the basement was expected to be fairly airtight. It was therefore necessary to provide air supply vents for the furnace. The installation of these has already been described in the section dealing with basement development.

9.4 Details of the upgrading work

The furnace was cleaned thoroughly, with particular attention to the heat exchanger body.

The nozzle sizes were reduced, to reduce the capacity of the furnace in accordance with the reduced heating requirement of the house.

A flame head retention burner was installed. This unit promotes increased mixing of the air and the oil in the combustion chamber, and thereby increases the combustion efficiency. Field tests conducted elsewhere on this unit indicate that it improves the combustion efficiency by typically 10% to 15%.

The furnace was tuned to maximum efficiency by adjustment of the air supply openings and damper.

A new filter was installed.

Before this work, the furnace efficiency was measured at 70.5%. After the the work, the efficiency was measured at 73.4%.

The warm air registers and cold air returns were relocated as shown in figure 2 on page 25. All registers were sealed at the point where they passed through the floor air-vapour barrier.

All warm air ducts were insulated with standard foil-faced insulation wrap, and both the cold air and warm air ducts were taped at all connections, right up to the furnace body. The contractor also insulated the warm air plenum immediately above the furnace. This was not required, and there may be some deterioration of the insulation in this area.

The cold air return ducts were left uninsulated. It was hoped that the heat loss from these ducts, together with heat loss from the furnace body, would maintain the basement temperature slightly above the freezing point. The effectiveness of this design has not been monitored.

It should be noted that though the oil furnace had been thoroughly inspected before upgrading and was considered to be in good operating condition, it failed, due to a crack which developed within the internal heat exchanger. The unit was replaced with a new natural gas furnace as a result of the availability of natural gas within the Town.

10.1 Assessment

The domestic hot water heater was an electric-powered unit, located in the basement. It was a fairly old unit and showed signs of water leakage and rusting.

10.2 Retrofit alternatives

Generally, there are three alternatives:

- Retain the unit, and try to make it as energy-efficient as possible by insulating it.
- Replace the unit with one of similar type, but with an improved efficiency.
- Replace the unit with one using a different fuel system.

Replacement should be pursued only if the unit is old or in poor condition. The options are virtually limited to an electric or a natural gas unit, but in this case the latter was out of the question since there was no local natural gas supply. If the unit is retained, it is generally good practice to equip it with one of the commercially-available insulation blankets. This is particularly true for electrical units in Saskatchewan, where the cost per unit of electrical energy is considerably higher than the comparable cost for oil or natural gas. Any heat that the unit loses to the house is therefore expensive heat, even though it contributes to the space heating.

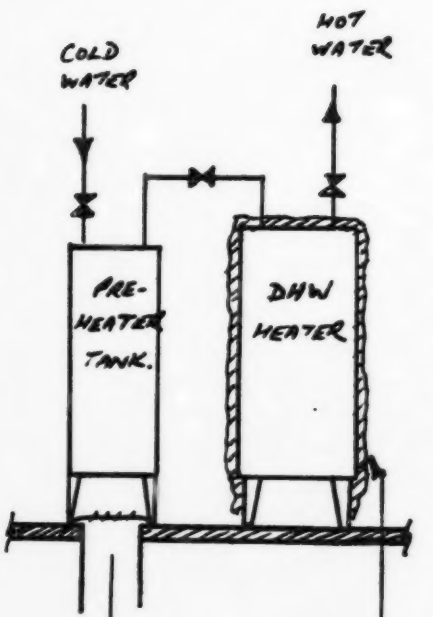
10.3 Factors affecting the choice

It was decided to replace the existing domestic hot water unit, because of its poor condition. A new electrical unit was the only practicable option.

Electrical units have an operating efficiency of slightly less than 100%. This is due to the heat lost from the unit body to the surrounding air. The efficiency can therefore be improved slightly by insulating the unit. The amount of heat lost from

the unit is then determined by the insulation level and by the temperature of the surrounding air. The air temperature in the basement was expected to be slightly above the freezing point, whereas that in the heated part of the house would be typically 20 C. The efficiency of the heater could therefore be improved slightly by locating it on the main storey of the house. Any heat it then lost would contribute to the space heating of the house.

The relocation of the heater gives only a marginal increase in efficiency, and is doubtfully cost-effective if it involves major re-routing of the plumbing system. But in this case the plumbing system required a major overhaul anyway, and therefore the relocation could be achieved at virtually no cost.



One of the advantages of relocating the heater was that it created an opportunity to demonstrate a preheat system in a practicable way. Energy costs are higher for electricity than for oil in Saskatchewan. Therefore, if some of the house heat can be used to pre-heat the hot water supply, the electrical usage of the domestic hot water heater will be reduced and the space heating requirements will be increased by an equivalent amount. There is therefore no net saving in energy consumption, but the trade-off of electrical consumption for oil consumption means that the owner will derive a total cost saving on the fuel bills.

10.4 Details of upgrading work

A new electrical domestic hot water heater was installed in the newly-constructed closet off bedroom # 3. The heater was wrapped with an insulating blanket designed for DHW usage.

A preheater tank was connected to the DHW heater. This tank holds 30 gallons of water. It is uninsulated, therefore the incoming cold water will absorb heat from the house air. This will heat the water from its incoming temperature, typically 4 C, up to a temperature close to that of the house air, typically

18 C to 20 C. Therefore, instead of raising the water temperature from 4 C to about 60 C, the DHW heater only has to raise it from about 20 C to about 60 C. This reduces the electrical heating requirement by about 30%.

The new closet contains an air duct register in the floor. Originally, this was a warm air duct located behind the bath-tub. The duct was converted to a cold air return, and the pre-heater tank, on legs, was positioned above the register. The warm house air was therefore drawn continuously around the pre-heater tank, thereby improving the effectiveness of this unit. Note that this also tends to give a slight reduction in the temperature of the cold return air on its way to the furnace. This reduction in return air temperature may produce a slight improvement in the operating efficiency of the furnace.

To allow an adequate flow of air around the pre-heater unit, the closet door was provided with a vent, and the door of bedroom #3 was undercut at the bottom.

With a house as airtight as this was expected to be, it is necessary to have a controlled ventilation system to prevent humidity build-up in the house air, and to maintain tolerable limits on pollutants and odours. The ventilation system consists basically of two fans: one exhausting stale air from the house and the other drawing fresh cold air into the house. This constant exchange of warm house air for cold outside air is responsible for a considerable heat loss - compared with the low heat loss of the rest of the retrofitted house. The heat loss can be reduced by incorporating a heat recovery device, such as an air-to-air heat exchanger, into the ventilation system design. Various types of heat recovery devices are now available for residential usage, and they can recover typically 50% to 70% of the heat that would normally be lost by ventilation.

A very simple ventilation system and heat recovery device was selected for the Maidstone house. Two ports were built into the rough opening of window #2, at the time when it was being blocked in. On completion of the main structural work, these ports were located in the re-modelled laundry room. A small Lossnay air-to-air heat exchanger unit was connected directly to these ports. The unit has two fans built into it, one for exhaust and one for fresh air intake. The unit is designed to be coupled to two ports, as was done in this case.

The unit has not been thoroughly tested in this application, since the house has been used mainly as a demonstrational centre. However, it has been observed by several visitors that the house appears to be stuffy and odorous. The cause of the poor air quality and subsequent problem of odours were traced to a malfunctioning oil furnace. A crack had developed in the internal heat exchanger within the furnace unit, allowing combustion gases to enter the heating loop and circulate to all liveable areas of the house. Details of furnace replacement are discussed in Section 9.4.

12.1 Assessment

The plumbing and electrical systems were generally below the minimum acceptable standard. The plumbing consisted of a mixture of various pipe materials, and the pipe routing was unnecessarily complicated and lengthy. This was doubtless due to several stages of re-modelling. The electrical system was particularly poor, with badly located lights, switches and outlets, indicating that the system had not been installed by a qualified electrician.

It was decided to completely remove the existing plumbing and electrical systems, and install new systems suited to the new layout of the house.

12.2 Details of upgrading work

The existing plumbing system was removed, and a complete new system was installed to match the new kitchen sink location, the new DHW heater location and the re-arranged layout in the bathroom.

As far as possible, all pipe runs in the basement area were laid inside the ceiling insulation, to prevent any freezing problems that might arise from excessively low basement temperatures. All exposed pipe was insulated with standard water pipe insulation sleeves. Particular attention was paid to sealing around pipes and vent stacks where they passed through the air-vapour barrier - both a floor level and at ceiling level on the main storey.

The electrical service connection was removed from the south porch before it was dismantled, and was relocated on the south wall of the house.

A special wood frame was constructed between the basement floor and ceiling to attach the electrical service panel, and a new electrical service panel was installed.

The existing electrical wiring system was removed or disconnected. A new electrical system was installed, with the emphasis on a more conventional location of lights, switches and outlets. Special circuits were installed for the new electric range location, the new DHW heater location, the new refrigerator location and in the new laundry area.

Attention was paid to the sealing of cable runs and outlets, etc., where these penetrated the air-vapour barrier.

A range of miscellaneous work was performed on the house to put it in good shape for the demonstrational program, or to rehabilitate some of the defective parts of the house. The main items were as follows:

- The ceilings and walls were painted.
- The kitchen floor was given a vinyl covering, and other floors were carpeted.
- A completely new kitchen sink unit and cabinet system was installed.
- The washbasin and lavatory were replaced with new units.
- New trim and baseboards were installed throughout the house interior.
- Soffits were repaired and painted.
- The exterior stucco was repaired where necessary, and the entire stuccoed area was painted to blend the original stucco with the new work around blocked-in windows, etc.
- A new eavestrough system was installed, to replace the inadequate original system. Splashpads were installed under the downspouts.
- The existing oil tank, for the furnace oil supply, was lying on the soil on the west wall of the house. This was provided with a metal support frame, mounted on concrete pads.

For details of costs, projected energy savings, and conclusions about this project, the reader is referred to the Overview Report, which is the first in this series of reports.

For further details of the work, the materials and the techniques, the reader is referred to the following appendix, which consists of the detailed specifications as given in the contract documents.